# Roses and Genetics

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Now that genetics, in partnership with biophysics and biochemistry, and under the new name of molecular biology, has become so publicised, it is interesting to remember that during the 'twenties and 'thirties cytogenetical work with roses played a considerable part in the earlier researches in this subject and especially in opening up new aspects of the study of evolution. In no other genus could such a comprehensive and comparative study be made, falling as it does into many different categories which could only be investigated otherwise by using a number of different genera.

The enormous number of wild-growing ROSA species, many of which are so well depicted for us in Miss Willmott's splendid monograph, extend widely all round the north temperate zone while several, by accident or design, have followed man into the south temperate zone. Certain species, very sweet-scented and with a propensity for doubling their petals, attracted the attention of man in the early stages of his civilisation and through the centuries were domesticated by him. These gradually, like his animals and foodcrops, produced new forms for his careful selection. The Greeks and Romans were particularly fond of these roses and by mediaeval times a firm basis was laid for what we now call the old-fashioned bush roses. During the last century the famous French rose-growers in particular evolved from these the hybrid perpetuals through hybridisations with *Rosa chinensis* and the tea roses, which eventually were to blossom forth into our magnificent hybrid teas of today.

Added to these is another completely distinct group of ROSA species, the briars or *Canina* roses, growing wild in Europe and Western Asia and important horticulturally as stocks. These have a most peculiar cytogenetic behaviour and geographical distribution, more or less coinciding with the greatest extension of the ice sheets of Pleistocene times, pointing to the fact that they are probably ancient hybrids of that period. Consequently there are many interesting evolutionary problems connected with them.

So, within one genus, we have every stage from the purely wild species, through the early cultivated forms to the most highly evolved garden forms of today, artificially created by the concentrated efforts of many great rosarians. Genetics was certainly not in the minds of the early breeders since its principles were unknown until 1900; nevertheless mutants were carefully preserved and many of their hybridisations were of great future genetic importance, especially the introduction of the previously elusive yellow shades by Pernet-Ducher at the turn of the century by using the yellow *Rosa lutea* from S.W. Asia and its magnificent mutant 'Austrian Copper', with petals coloured rich nasturtium-red on the inner surface, providing the basis for the long line of bicolours which are so popular today.

The Abbé Mendel had carried out his famous experiments on heredity in peas in the 1860s, but these were disregarded and forgotten until they were rediscovered in 1900. Put very briefly, he had proved that normally every individual carries two complete sets of hereditary characters, one received from the father and one from the mother at fertilisation. At the formation of its own germ cells these will again contain only one set of characters, but these, although unchanged, will have been reshuffled so that any differences between the original parents will segregate out in subsequent offspring, giving different combinations.

Through crossing different varieties of peas Mendel found that in the case of equivalent characters such as yellow or green seeds, tall or dwarf stature, one would be dominant over the other (the recessive), hiding it when they are both present together. Only when two recessives come together can this character show itself under ordinary conditions. By the laws of chance this can theoretically happen once out of every four times, which is also true for the meeting of the two dominants, both the pure dominants and the pure recessives resulting obviously breeding true. In the remaining two, however, the dominant will meet the recessive, but outwardly only the dominant will show so that out of every four there will be three apparent dominants to one recessive. This famous 3:1 ratio for the inheritance of any one pair of characters and the purity of each unit character involved, were the key principles for Mendelian breeding.

In England William Bateson and Miss E. R. Saunders at Cambridge, and C. C. Hurst in Leicestershire had been working on similar lines at the end of the century without discovering the whole truth, though they were very near to it. The R.H.S. was extremely interested in this work and as it was realised from their results that the secrets of heredity could only be discovered by minute observations on hybrid behaviour, the Rev. W. Wilks, then Secretary of the Society, arranged an international conference on hybridisation in 1899 at which the three English workers and others at home and from abroad read papers on the subject. Much interest was aroused and when Mendel's lost paper was discovered the next year it was seen that it held the missing clues in dealing with each character as a separate unit, retaining its individuality from generation to generation.

Experiments were put in hand in many countries during the next decade to test the truth of Mendel's Principles in various animals and plants and they were found to hold true in all those examined. Mendelism was rechristened *genetics* and the unit characters *genes*: the next step was to discover what these mysterious entities were which appeared as pairs in any individual and singly in its germ cells, fertilisation restoring the paired condition in the new individuals arising. Microscopists who had been examining the cells in animals and plants had discovered that each cell contained minute worm-like bodies which took up dyes so readily that they were named "chromosomes" or coloured bodies. As work proceeded it was found that each bodycell contained the same number of chromosomes in any individual, and usually in every individual of a species though it might be different in other species, but when they examined the germ cells they found the number was reduced to half. Putting two and two together it was suggested that here was the perfect mechanism for Mendel's segregation of characters, but this had to be proved. During the second decade T. H. Morgan and his colleagues in America set out to do this, using the minute fruitfly, Drosophila, which could be bred in enormous numbers and most conveniently possessed only four pairs of chromosomes which made the work less complicated. If the genes were carried by the chromosomes they should therefore work in four groups in the germ cells of this fly and by an immense number of experiments this was not only proved but many of the genes were actually "mapped" for their positions within these four chromosomes.

Genetics had arrived thus far at the end of World War I; there was considerable disbelief in the new ideas, as was the case in the early days of Mendelism. Hurst, who had always believed in the chromosome theory, returning from the war in late 1919, saw that this new work had also to be extended to other animals and to plants in the same way that the Mendelian work had been. Before the war he had had an extensive experimental station for this at Burbage in Leicestershire, where his researches covered horses, rabbits, poultry and many different kinds of plants, including roses. Already some workers in America were starting on various species of plants to correlate the chromosomes with the genetic characters, but Hurst felt that it was necessary to go beyond this. He was extremely interested in the problems of evolution and he realised that if the genes were located in the chromosomes an examination and comparison of the chromosomes of the various species in a large genus should give considerable enlightenment on this too, pointing out ways by which they had evolved.

This was where the roses came in. He had a large and representative collection of species and cultivated roses from all over the world and genetical work was already in progress with some of them. He determined to extend this by investigating the chromosomes too and in 1922 we went up to Cambridge for the necessary laboratory accommodation and facilities. Fortunately just about this time a Swedish botanist, G. Täckholm, published an account of work he had done on ROSA chromosomes which was extremely useful since, in addition to those he had worked with in Scandinavia, he had done a number of those in the very excellent collection of species then at Kew, largely the result of the great pre-war collections made in that hotbed of speciation of S.E. Asia, though there were many from other areas.

His work showed that ROSA chromosomes were amazingly interesting, far beyond anything Hurst had hoped for and likely to prove most profitable for his research. For ROSA proved to be one of the genera containing many species known as polyploids in which there are more than two complexes of chromosomes in an individual. The basic chromosome number is seven (haploid), and in the ordinary diploid condition 14 chromosomes are present in the body cells of the individuals of the many species belonging to this category; but there are also tetraploids with four sets of chromosomes (28), hexaploids with six (42), and octoploids with eight (56).

The *Caninae* roses, some forms of which were also examined by Blackburn and Harrison in Newcastle about this time, showed a very queer state of affairs since they were pentaploids with five sets of chromosomes (35), of which only two sets—14 chromosomes—paired together, the remaining three—21 chromosomes—continuing unpaired. In the pollen cells the seven pairs divided normally giving a varying percentage of healthy pollen grains with seven chromosomes; the unpaired chromosomes were most erratic, a few getting included in some of the main grains, others forming small grains themselves, in either case causing sterility. The formation of the eggcells was curious in the extreme, for in this case all the single chromosomes tended to be included with one of the sets of the reducing pairs so that female germcells had 28 chromosomes which, when fertilised by pollen carrying 7, restored the original number of 35 in the progeny.

Actually these roses are very largely apomictical (i.e. setting seed vegetatively without reduction or fertilisation) which accounts for their rich harvest of heps in spite of much gametic sterility. Nevertheless the hybrids which occur from time to time show that this irregular fertilisation can take place. The great point is that here too the chromosomes are working in sets of seven, which made them very useful for experiment.

The chromosomes of the garden roses at that time were not so complex as might be expected, most so far as examined being diploid or tetraploid, with some triploids occurring as hybrids between these and a few higher polyploids arising through crosses with *R. canina* (*R. alba*, etc.), in the Penzance Briars (hybrids between *R. rubiginosa* and various garden roses), and a few others. The work done with these was described by Hurst in the R.H.S. Journal in 1941 under the title of *Notes on the Origin and Evolution of our Garden Roses*, and reprinted in *The Old Shrub Roses* by Graham Thomas (1955).

There must be far greater complexities now after another forty years of intensive hybridisation by many rose growers and through the introduction of other species. Hurst himself set out to incorporate into the garden roses the desirable qualities of the strong-growing and beautiful American species *R. nutkana* (a hexaploid), crossing it with a popular garden rose of the 'twenties, 'Red Letter Day', with a very high proportion of *R. chinensis* blood which made it extremely free and perpetual flowering.

The result was the shrub rose, 'Cantab', which gained the Cory Cup at the

R.H.S. in 1940. This is illustrated in Edland's *Pocket Encyclopaedia of Roses* (1963, p. 111, No. 345). The bush, which runs up to a considerable height, covers itself with large single flowers up to 4 inches across, of a rich carmine pink. It is also fertile and inherits the late, hard-fruiting habit of *R. nutkana* so that it puts up another display in late autumn. Although it is only summer flowering itself it carries the recessive character for perpetual flowering from 'Red Letter Day' and it was intended to breed from 'Cantab' to raise perpetual-flowering bush roses, but due to the war this was not possible. One hopes that use will be made of this first generation hybrid which contains other desirable but hidden recessive qualities including the double flowering of 'Red Letter Day' and the robust caney habit of *R. nutkana*.

To return to the wild species: polyploidy, now so much a part of plant genetics, had scarcely been recognised at the beginning of the 'twenties. A very few plants which showed gigantism in all their parts had been found to have double the number of chromosomes and Japanese botanists had found a polyploid series in *Chrysanthemum* species, but the implications of this were not realised even by those involved, much less by other biologists. Chromosome number had always been regarded by most as merely another systematic character in the days before Morgan had shown that the chromosomes carried the genes and this was not by any means universally accepted as yet, so little having been done from this standpoint except in Drosophila.

During 1922–23 the material Hurst had taken from his own collection, and in the wild, was examined and we found that it completely agreed with Täckholm's work. By this time quite a considerable number of species and garden forms had been covered and Hurst was able to correlate these results with the systematic position in ROSA. He began to realise that the wild-growing polyploids were not just plain duplicated diploids as was found for some garden roses, but appeared to contain the characters of two, three or four diploid species according to whether they were tetraploid, hexaploid or octoploid. This was an entirely new idea, though one or two cases were known in cultivated plants in which a sterile hybrid had produced a fertile form by the duplication of its chromosomes. These first ROSA results were reported at the British Association at Liverpool in 1923.

One of the greatest conundrums of the early geneticists arose from the fact that in their experiments it seemed as if much variation proceeded from an "unpacking" of a considerable number of genes contained within a wild species, especially under domestication. If this were so, how did they get packed up originally? It has to be remembered here that for many people special creation was still by no means forgotten. Linnaeus had believed that species were specially created but varieties arose afterwards. Darwin's great work on the origin of species by the natural selection of variations had been against this idea, but so little was as yet known as to the causes of variation that there was still no definite proof of this and Darwin's theories were being questioned by a number of people in consequence.

Hurst saw that in these polyploids there certainly was a very considerable opportunity for this packing up by the bringing together of less complex species to form more complex ones which, through the greater number of chromosomes and genes contained, had far greater powers of mutation and also of response to differing environments. The work of other people, too, was beginning to show that not only were whole chromosome complexes involved in this build-up, but duplications of single chromosomes could occur, of parts of chromosomes even, all adding to the complexity of species and creating the condition which had so puzzled the early workers.

The rose work went forward rapidly. We visited and took material from all the famous gardens, including the fabulous Roseraie de l'Haÿ near Paris. Much interest was aroused, especially in America, and a vast amount of criticism everywhere. Only the most advanced biologists had as yet reached the point of accepting that genes might be carried by chromosomes; that they could occur in such complex groupings was another big pill to swallow. Although the rose work received much attention and many people came to see the experimental collections at Burbage and Cambridge, few people were conversant enough with the systematics of this very large and difficult genus to be able to follow it easily.

In July 1928 Hurst gave an outline of the experiments to date at the great International Rose Conference in London, an extended and fully illustrated paper being published in *The Rose Annual* for 1929, showing that the classification of ROSA species could be correlated with the chromosome numbers, explaining the many difficulties experienced by earlier rosarians in dealing with this very complicated genus, rendered so by reason of its polyploid condition which creates much otherwise inexplicable overlapping.

By this time the chromosomes of 674 species, varieties and hybrids had been examined and it is probably still true to say no other genus has been so widely covered. During the next few years this was increased to over 1,000 by ourselves and others. Unfortunately most of the great collections of the very beautiful rose species have been lost during this very disturbed century, Miss Willmott's being destroyed during the first war and the greater part of the one at Kew during the second, with smaller ones falling victims to the lack of labour. Unfortunately there is no present hope of replacement of the great Asiatic species owing to political conditions. The fatal habit of Botanic Gardens of distributing seeds from open flowers has resulted in various hybrids being perpetuated as the real species, of which very few now remain except as illustrations in the great pre-war rose monographs.

The work on the chromosomes of various other plants and animals was steadily advancing everywhere, giving fresh proofs of the possible courses of evolution. Wheats in particular showed diploids, tetraploids (macaroni wheats) and hexaploids (bread wheats) which were eventually traced out as ancient species hybrids in which the chromosomes had become duplicated. Today this production of new species by hybridisation and the duplication of the chromosomes of the sterile hybrid to make a fertile new species is a commonplace, both by artificial experimental means and as occurring naturally in the wild; but it was in ROSA that this was first realised as an evolutionary factor opening up new possibilities in the creation of new and more adaptable species, as has been occurring in nature through long aeons of time.

Hurst was assiduously collecting information on all the various types of chromosome and gene changes which were being discovered, many of which were also found in ROSA, showing how these could bring about the many changes necessary to build up all the complexities of the higher animals and plants—"from amoeba to man". Bringing all this together with the rose results he published it as a book, *The Mechanism of Creative Evolution*, in 1932 which certainly hit the world headlines for all the new ideas it contained.

No other genus could have shown so conclusively the proofs of the progress of evolution, not only naturally but, in later centuries, in the great florescence of garden roses, through human controls, thus illustrating how man has increasingly taken over and speeded up these processes by his domestication and breeding of animals and plants and the making of better environments for their success. The future of creative evolution now lay in the hands of man, for better or for worse, according to how he used his new powers. The final and most important control man has yet to exercise is upon himself and unless he can do this very quickly, both in the control of human populations and of his greed for power, extending to the danger of annihilation by starvation or by atomic or biological warfare, his new knowledge, which could be so beneficial for all, will be of no avail.

With the cooperation of biophysicists and biochemists, together with the new refinements of electronic techniques in the laboratories, the mystery of the actual genes themselves has been revealed during the past fifteen years, showing them to be real molecular entities acting as chemical codes, or messages, handed down by the chromosomes from generation to generation, and from cell to cell, giving the information for the various processes through which the development of a complete organism can be achieved.

With the new genetical knowledge gained in recent years man becomes increasingly in control of biological development and the alleviation of disease, in addition to the earlier genetic methods of breeding better food animals and plants. This has frightened some people into the belief that science might tamper too much. This belief stems largely from ignorance and the misrepresentations of facts by reporters, who make terrifying assertions without scientific knowledge.

It is pleasant to think that the rose, so beautiful and well-beloved, should have played such an important part in the unravelling of the genetic problems so necessary for the future betterment of man and his environment.